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That I am knowledgeable in the English language and in the language in which the below-identified international application was filed, and that I believe the English translation of the international application No. PCT/EP 2004/013444 is a true and complete translation of the above-identified international application as filed.

I further declare that all statements made herein on my own knowledge are true and that all statements made on the information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Section 1001 of Title 18 of the *United States Code* and that such willful false statements may jeopardize the validity of the application or any registration resulting therefrom.

Date: April 10, 2006

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10/580723

AP20R6C1PGT/PTG 24 MAY 2006

**MAGNETIC BRAKE FOR
CONTINUOUS CASTING MOLDS**

10/580723

APPROVED FOR RELEASE 23 MAY 2006

The invention relates to a continuous casting mold, in particular a thin slab mold, in which the flow of liquid metal in the mold is influenced by a magnetic field which is generated by permanent magnets arranged on the mold, and wherein the permanent magnets have, over the width and/or height thereof different magnetic strengths or are spaced from each other by different distances for a different field strength.

The use of magnetic means for braking and homogenizing the liquid metal flow is a known technique and is described in numerous technical documents. The installation components, which are described in the documents, have all large masses which make difficult the oscillation of the mold that is necessary for the operation.

The document EP O 880 417 B describes a magnetic brake for casting metal in a mold and which consists of a magnetic core and a coil supplied with permanent current or low-frequency alternating current. There is further provided a return line for closing the magnetic circuit.

The progress in the development in the field of permanent magnets (hard ferrites, rare-earth magnets) opened, meantime, new uses for possible field

strengths of permanent magnets, which permanent magnets appears to be a suitable alternative for use instead of the above-described electrical magnet.

It has already been proposed to replace the electromechanical brake (EMBr) equipment, which was used up to the present for generating the magnetic field (field coils, electrical control, outer yoke for conducting the magnetic flux, etc.), with permanent magnets which are directly mounted on the mold.

The document EP 0568 579 describes a method of controlling the flow of the molten metal in a non-solidified metal region of a casting mold, wherein the mold is supplied with at least one primary flow of the molten metal and a cast strand is formed, and wherein at least one static magnetic field is generated by poles which are arranged adjacent to the mold and consist of permanent magnets. The magnetic field serves for breaking the primary flow of the molten metal flowing in the mold and for splitting the primary flow and for controlling the produced secondary flow. The magnetic field is so arranged that it acts over the entire width of the strand formed in the mold. The magnetic field should extend in a plane extending perpendicular to the cast direction and at level at which the magnetic field strength reaches its maximal value and can be varied

within a range of from 60% to 100% of the maximal value, while simultaneously the field strength has a maximum value of 500 Gauss at a level with the highest outer surface/meniscus of the molten metal. The magnetic field is controlled and distributed by providing displaceable magnetic poles and/or adjustable core members.

The document EP 00 40 383 B1 describes a method of stirring the non-solidified region of a cast strand, wherein the strand is formed in a mold, and the cast steel flows through a pouring spout or directly into the mold. There, where the cast steel penetrates the melt already amassed in the mold, at least one static magnetic field is generated that brakes the cast or pouring steel and so splits it that its momentum is weakened or absorbed. The device, which is provided to this end, can be formed of one or several permanent magnets.

Document JP 08155610 discloses a rectangular mold in four corners of which permanent magnets are arranged for generating South and North magnetic fields.

Permanent magnets have a substantially smaller configuration at the same magnetic induction field strength and, therefore, a significantly reduced mass.

They do not require any additional means for conducting a magnetic flux in form of an outside yoke. When necessary, it is sufficient to use ferromagnetic materials, which are available in the mold frame, for closing the magnetic flux circuit.

However, use of permanent magnets requires other special procedures. In the state of the art, permanent magnets are used as possible sources of static magnetic fields but only as equipment for the case when the magnetic field is generated by current coils with direct current DC or low-frequency alternating current, as discussed above, but not, however, for permanent magnets.

Because permanent magnets have no switch for turning on and off, they require special safety measures for installation and monitoring of the equipment. In distinction from the alternating current drive, special methods of equipment are necessary for operating a continuous casting machine.

With a magnetic brake, there are provided, on both sides of the mold opposite each other, permanent magnets for generating a magnetic field. The induction field strength at this arrangement follows, at a spacing between the permanent magnets in the intermediate space, an equation:

$$B(z) = 2 \cdot B_0 \cdot \cosh \frac{\pi \cdot \left[z - \frac{d}{2} \right]}{h}$$

wherein B_0 is the induction field strength of one of the permanent magnets, z -distance from one of the magnets, d -distance between the magnets and h -operating height of the magnets. The operating height is determined by measurement. π is the number Pi ($=3.14\dots$), and \cosh is a hyperbolic cosine (see Fig. 1).

The object of the invention is to provide, on a continuous casting mold, means for varying the magnetic field strength of permanent magnets.

According to the invention, this object is achieved by differently adjusting the permanent magnets in groups for a different distribution of the field strength.

According to an advantageous embodiment of the invention, the permanent magnets are displaced on displaceable and/or pivotable adjusting means over the mold for adapting the field strength.

This is effected, e.g., by changing the distance of the magnets from each other, advantageously, by pivoting the carrier of the permanent magnets away from the mold. There exist further possibilities by a direct method with rotatable spindles or hydraulic cylinders (see Fig. 2). In case of pivoting of the magnet

carrier away from the casting mold, the weakening of the field strength follows the following equation:

$$\Phi = |\vec{B}| |\vec{A}| \cos(\angle(B,A)),$$

where Φ is magnetic flux, B is magnetic field strength, A is pass-through surface to the casting mold, and \cos is cosine of an angle between the vector of the magnetic field strength and the vector of the surface normal of the pass-through surface. The varying of the magnetic flux is effected over the field weakening B according to the equation $B(z)$ and the angle. In case of the mechanical displacement, as changing of the distance, changing of Φ is effected only over the field weakening B according to the above-mentioned equation over $B(z)$.

The rotation facilitates, on one hand, detachment of the magnets from the pass-through surface, then, according to the instructions for mounting of these permanent magnets, they are put on an edge and, thereafter, are placed on the carrier with a constantly diminishing angle (see Fig. 3). The magnets are not placed directly on the carrier from a ferromagnetic material, rather, to facilitate detachment for rotation or mounting, a layer of a non-ferromagnetic material is

provided therebetween. This can be an austenite steel, however, a plastic sheet with a thickness of about 1mm suffice. The non-uniform distances of the magnets to the pass-through surface, which are associated with rotation, are magnetically equalized by a pass-through body, the water box of the casting mold of a ferromagnetic material.

There exist two configurations of the casting mold, a mold with a recess for a magnetic brake advanced from outside, and a configuration with a magnetic brake integrated into the water box. For both cases, the following equipment is necessary:

Casting moldings with window for a magnetic brake applied from outside:

The field strength of the magnetic field, which is generated by permanent magnets, should remain adjustable. To this end, the permanent magnets are mounted on the teeth of a rake that engages the reinforcing ribs of the water box of a casting mold. A device provides for adjustment of the distance of the teeth to the mold by displacement. Thereby, it is possible to vary the strength of the magnetic field. The device can be displaced by a mechanical spindle or a hydraulic cylinder.

Casting molds with an integrated magnetic brake:

The electrical device, which was used for generating a magnetic field, is removed, and then a device for holding the permanent magnets is mounted on an uncovered ferromagnetic block (the pass-through window) in the water box. This device is displaceable by rotation and, thus, the magnetic field is varied. The device can be displaced by a mechanical spindle or by a hydraulic cylinder. In addition, there exists a possibility to have this device rotate about an axis on the lower edge and, thereby, to provide for changing the distance between the permanent magnets and the ferromagnetic block. This likewise provides for adjusting the magnetic field strength.

Permanent magnets are so strong that they cannot be made as large-surface elements. Such a magnet can explode under its own field strength, i.e., actually be destroyed. One is thus compelled to make large-surface magnets for the width of a continuous casting mold of a plurality of separate magnets which are glued onto a large-surface carrier of a ferromagnetic material, in order to combine magnetic flux densities of the plurality of separate magnets into a large-surface magnetic flux which exercises a metallurgical effect in the mold.

It is also of importance that by effecting the same alignment of the magnetic poles, small magnets are not arbitrarily arranged tightly next to each other and, finally, the same poles should be repelled. Therefore, one is compelled to form the magnet carrier of several layers because the still open intermediate space of the first layer should be covered in the second layer by permanent magnets.

Further, with a rake (comb-shaped brake), the magnets must not only be located on the teeth of the rake but rather on the back side of the magnet carrier (rake) of a ferromagnetic material and, here, again of several layers, because otherwise the necessary magnetic flux density in the metallurgical section of the mold would not be reached.